Acoustic Wave Biosensors

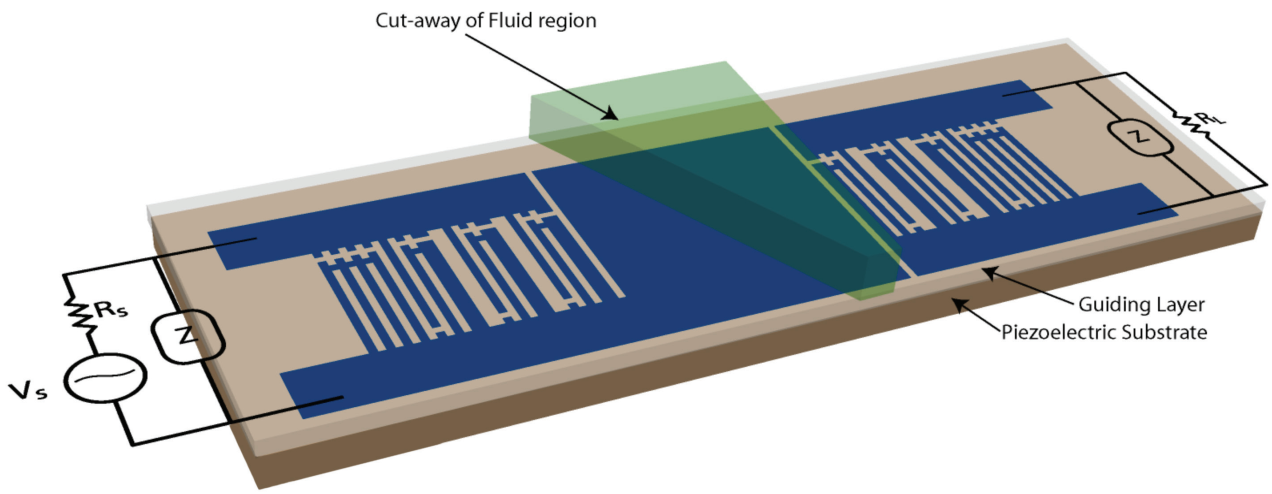

Figure 1: Schematic diagram of SAW sensor for detection of biological pathogens in fluids

Sensitive and selective pathogen detection for environmental sensing and medical diagnostics

Surface acoustic wave (SAW) sensors (Figure 1) have been routinely applied in the fields of chemical and biological sensing. Because the acoustic energy is confined to a thin surface region of the sensor substrate, SAW devices are highly responsive to changes in mass or viscosity at the sensor surface. However, developing sensors with sufficient sensitivity and selectivity to detect biological pathogens in liquids – for example, in water or in blood – has proven to be a challenge. Sandia researchers have addressed this problem by creating a mathematical model of the fundamental interactions between the electrical and mechanical properties of the piezoelectric crystals at the heart of these sensors. With this model, one can make detailed simulations of SAW behavior, selecting the optimal crystal orientation, acoustic mode, electrode placement, waveguide dimensions, and operating frequency for sensor performance.

Using design parameters determined with the model, researchers have fabricated microsensors (Figure 2), where each acts like a miniature analytical balance, weighing the biological pathogens that bind to its surface. These pathogens are captured very selectively by a monolayer of specific biological receptor molecules – antibodies, short peptide chains, or single-strand DNA – capable of distinguishing between closely related pathogens. One can think of the SAW microsensor as a spring with a small weight bouncing at one end. As the pathogens stick to the surface, the weight on the spring increases, which causes the speed of the spring's oscillation to decrease. By measuring the oscillation speed or, equivalently, the oscillation phase shift, one can determine how much of the pathogen has been captured. With this technique, biological warfare and infectious disease agents have been detected and identified.

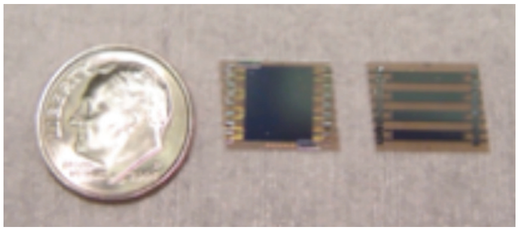

Figure 2: Optimized SAW sensor arrays for pathogen detection

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What makes this a particularly useful device is that the SAW microsensor can detect minute mass differences. In early work with this sensor, Sandia demonstrated the ability to detect as few as 800 spores of an anthrax simulant (Figure 3) in a background of 10,000 genetically similar spores. In a later collaboration with the University of New Mexico Health Sciences Center, detection limits below 1 ng/cm^2 for viruses were achieved. Sandia has also been able to detect viruses in complex, real-world samples including river water and sewage effluent without any sample pre-treatment.

These sensors could make a significant impact on the field of medical diagnostics, where their small size, sensitivity, and selectivity would permit diagnostic tests currently found only in medical laboratories to be performed in a physician's office. To address this need, Sandia has developed a handheld instrument (Figure 4) that incorporates arrays of SAW microsensors that operate on batteries and display results on a personal digital assistant (PDA). R&D Magazine recognized this instrument, being commercialized by Adaptive Methods, Inc., with an R&D 100 Award for one of the top new products of 2010.

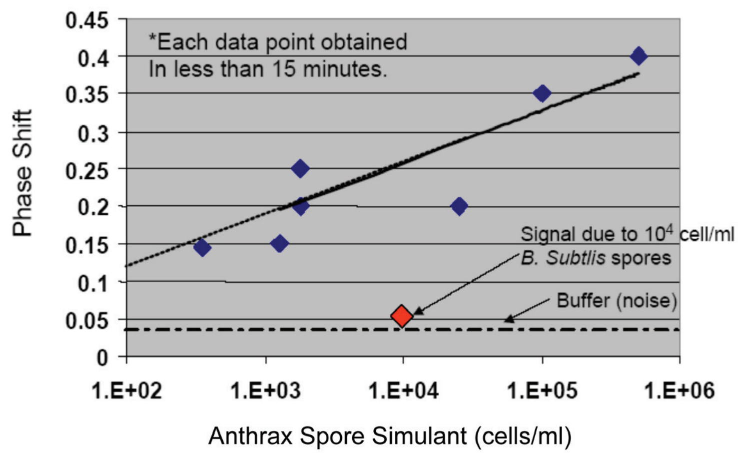

Figure 3: Microsensor results with Anthrax simulant

Figure 4: Portable, handheld instrument incorporating SAW microsensor arrays and a PDA.